# Kinetic Metallization

November, 2003

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# Report Documentation Page

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13. SUPPLEMENTARY NOTES
**23rd Replacement of Hard Chrome Plating Program Review Meeting, November 18-19, 2003, Cape Canaveral, FL. Sponsored by SERDP/ESTCP.**

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
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**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

# Kinetic Metallization

- Impact Consolidation Process
  - Feed-stock: fine powder
  - Accelerant: inert light gas
- Solid-state Consolidation
  - No Bulk Melting
  - No Liquid Chemicals
- Environmentally Innocuous
  - No Particle or Hazardous Gas Emission

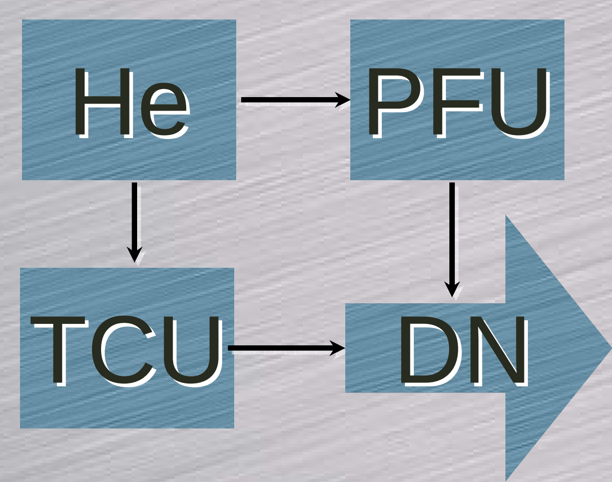
# KM–CDS

First KM-CDS Shipped!!
Buyer: US Naval Academy
Located: NAVSEA-Carderock


- Coating Development System
- Desk sized
- Production unit
  - Same footprint
  - Remove spray enclosure

# Critical Components

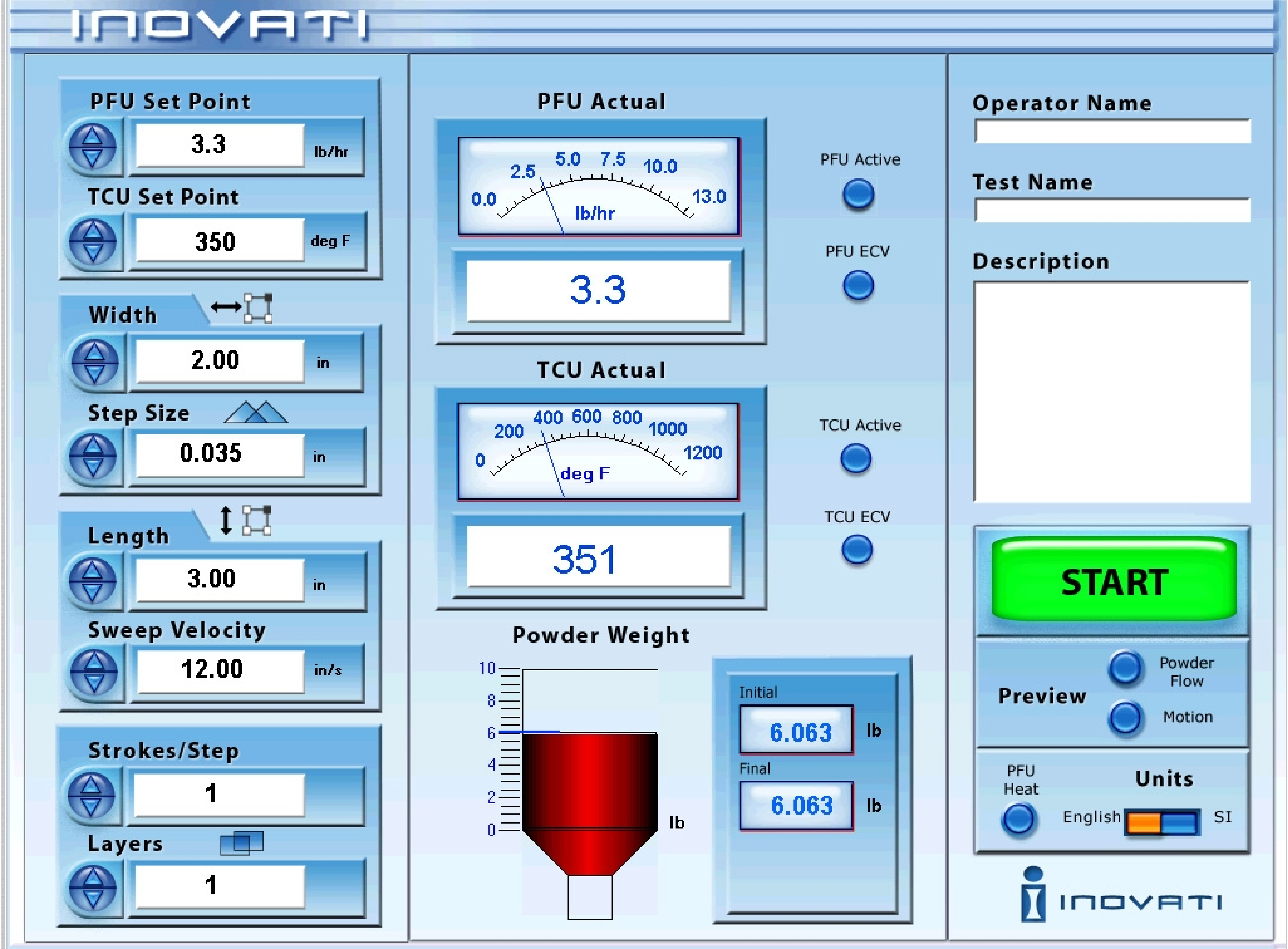
- Powder Fluidizing Unit
  - Closed-loop mass-loss control
- Thermal Conditioning Unit
  - Low power
- Deposition Nozzle
  - Fricton compensated




PFU

TCU

DN


INOVATI
PFU Set Point
3.3
lb/hr
TCU Set Point
350
deg F
Width
2.00
in
Step Size
0.035
in
Length
3.00
in
Sweep Velocity
12.00
in/s
Strokes/Step
1
Layers
1
PFU Actual
0.0
2.5
5.0
7.5
10.0
13.0
lb/hr
3.3
TCU Actual
0
200
400
600
800
1000
1200
deg F
351
Powder Weight
10
8
6
4
2
0
lb
Initial
6.063
lb
Final
6.063
lb
PFU Active
PFU ECV
TCU Active
TCU ECV
Operator Name
Test Name
Description
START
Preview
Powder Flow
Motion
PFU Heat
Units
English
SI
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# Robotic Control

- Compatible with any robot
- 5-pin connector provides
- All KM power/control interface

# So, how does it work?

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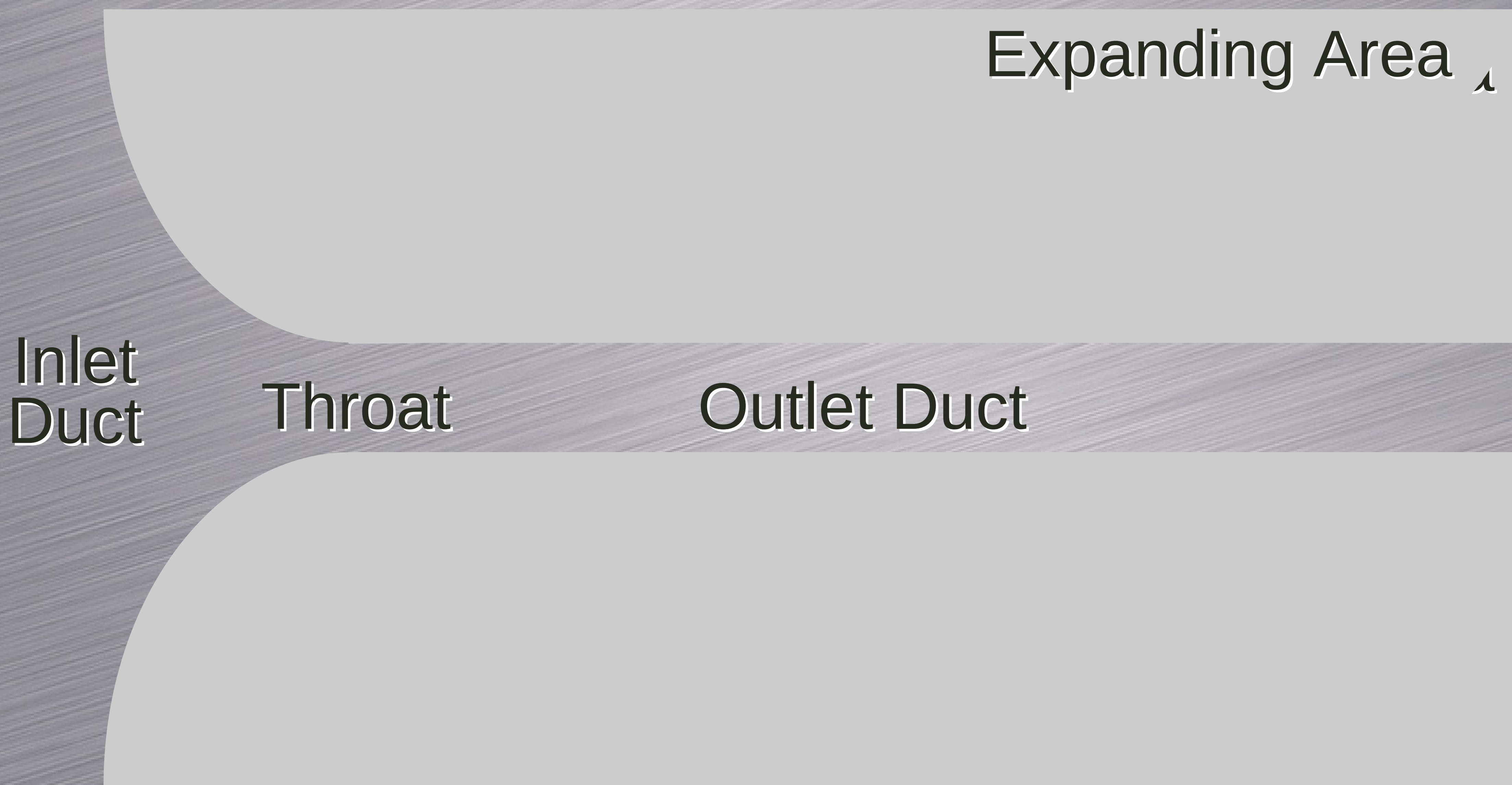
# Particle Velocity!

- KE = 1/2 • mass • Particle Velocity$^2$
- KE α
  - Deposition Efficiency (Cost)
  - Deposition Density (Quality)
- Gas velocity is a means not an end
- Particle velocity
  - *f* (gas ***velocity*** X gas ***density***)

# Nozzle Design

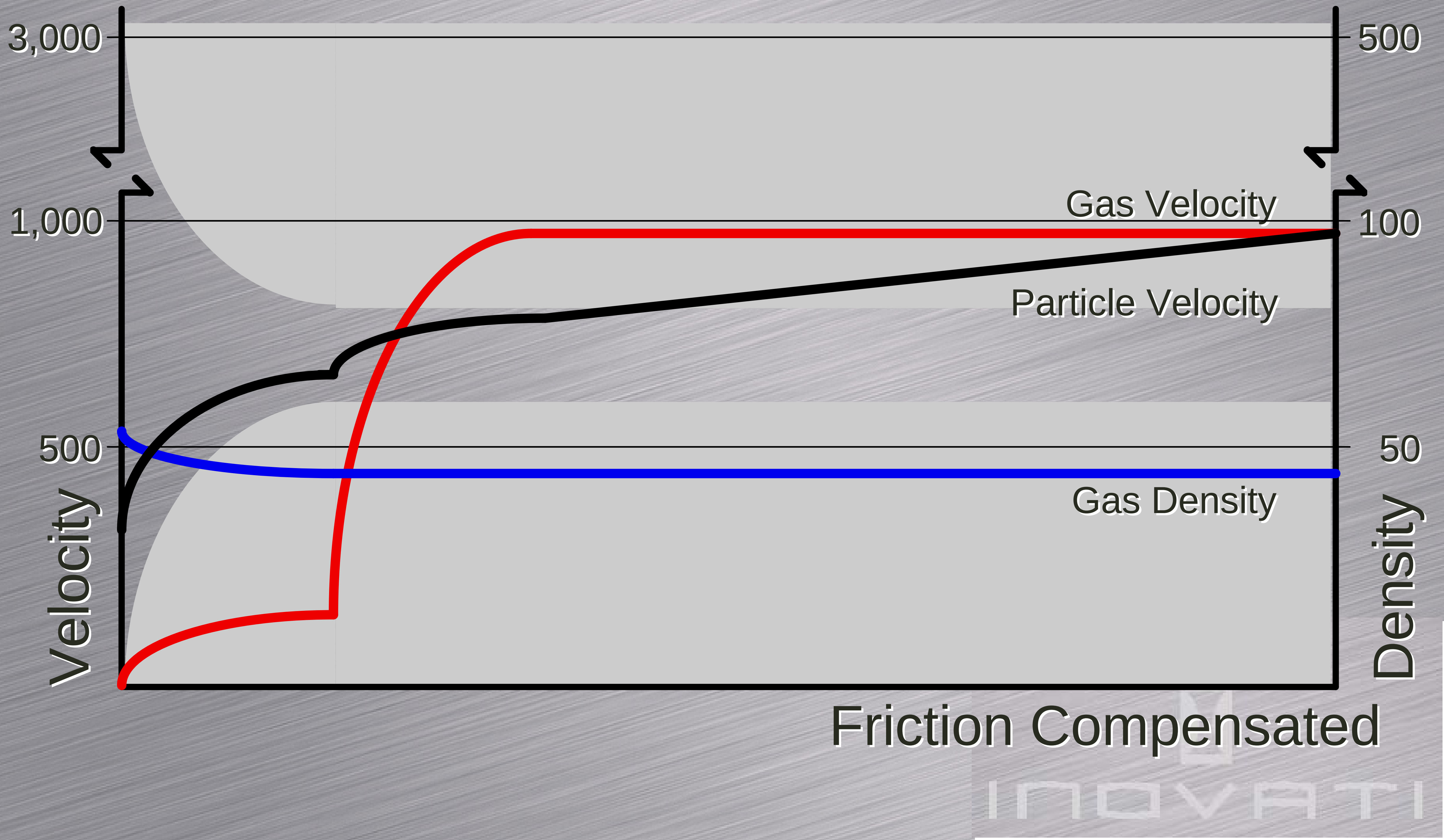
- Nozzle Anatomy
- Exit duct design
  - Increasing Area
    - Supersonic
  - Constant Area
    - Friction Compensated
    - Sonic

# Nozzle Anatomy

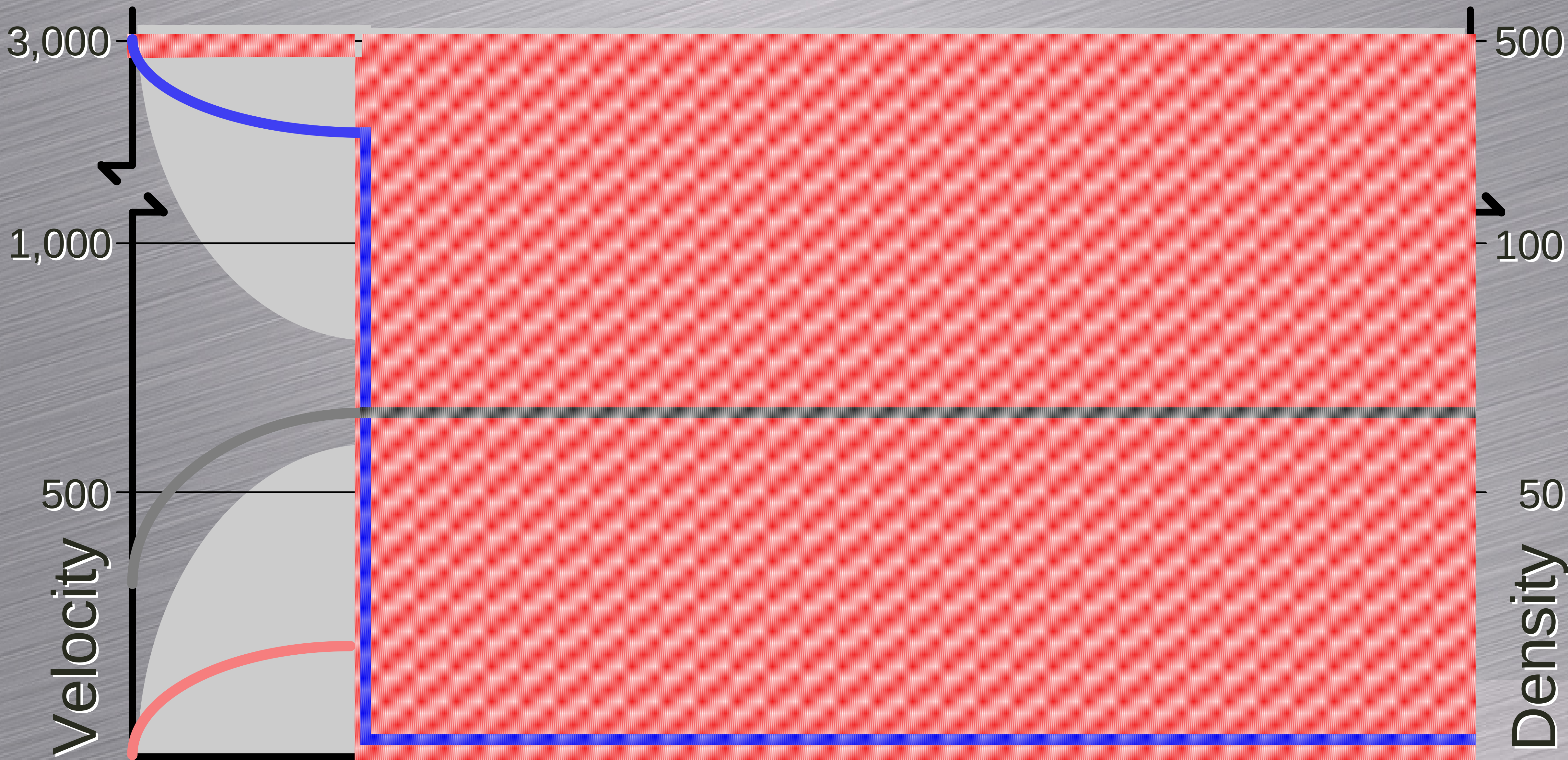


# KM Sonic Nozzle

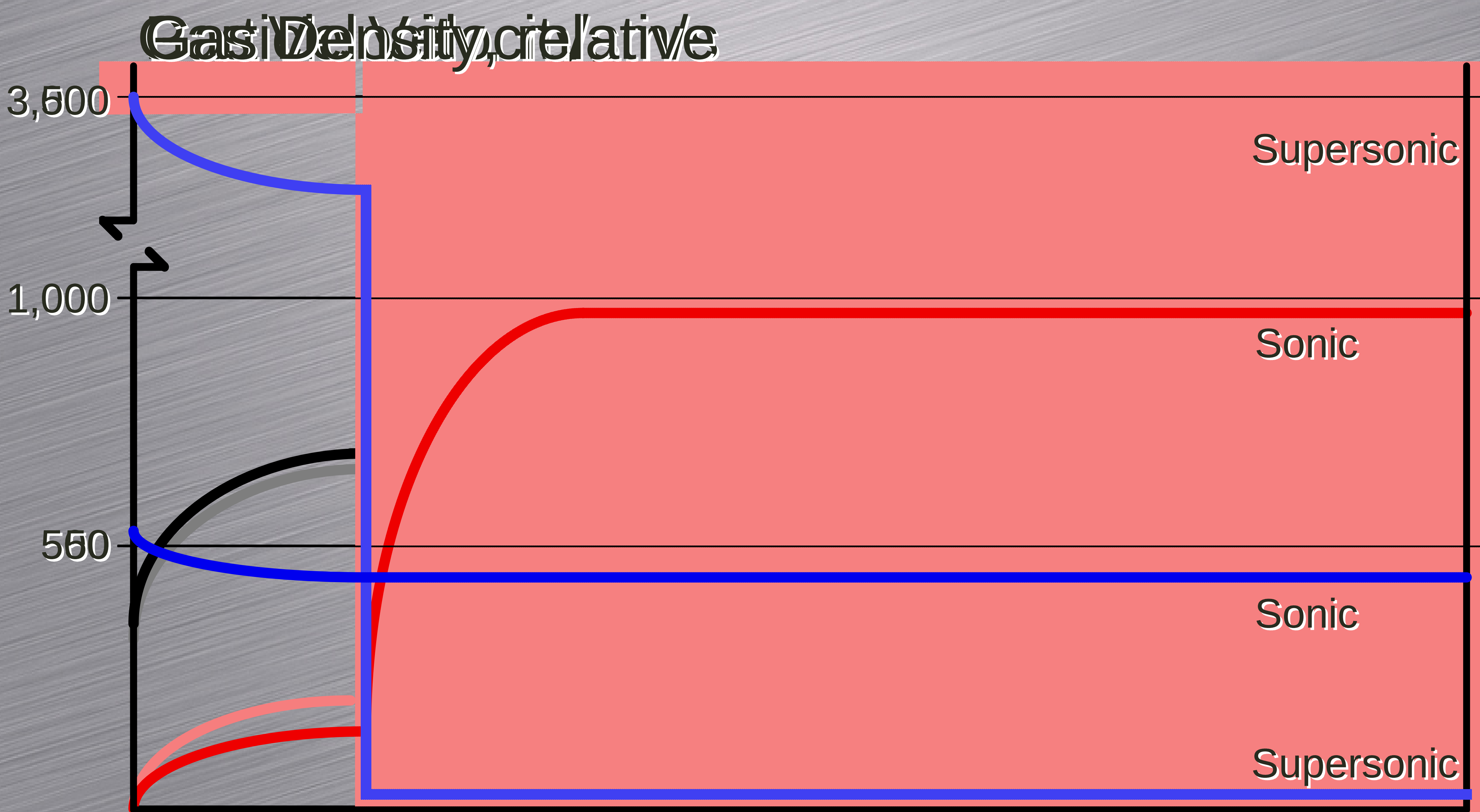
Constant Area Nozzle modified to compensate for flow friction



# Supersonic Nozzle



# Sonic vs. Supersonic



# Why Not Air?

| Nozzle | **Supersonic** | **Supersonic** | **Supersonic** | ***Sonic*** | |
|---|---|---|---|---|---|
| Accelerant | Air | $N_2$ | He | He | |
| Max Particle Velocity, m/s | [redacted] | 330 | 960 | 960 | X √T |
| Heat Input, W | 8,000 | 8,000 | 25,000 | 2,500 | |
| Explosion/Fire Hazard | [redacted] | Ti, Nb, Hf, Zr, U, Th | — | — | |

# Nozzle /Accelerant

| Nozzle | Supersonic | Supersonic | Supersonic Recycle | Sonic | Sonic Recycle |
|---|---|---|---|---|---|
| ***Accelerant*** | N2 | He | He | He | He |
| ***Pressure, psi*** | 500 | 500 | 500 | 50 | 50 |
| ***Flow, SCFM*** | 26.5 | 75 | 75 | 7.5 | 7.5 |
| ***Cost, $/SCFA*** | 0.04 | 0.10 | 0.03 | 0.10 | 0.02 |
| ***Cost, $/min*** | 1.06 | 7.50 | 2.25 | 0.75 | 0.16 |
| ***Cost, $/lb*** | 9 | 150 | 32 | 15 | 3 |
| ***Capital, $*** | — | — | 1,000,000 | — | 50,000 |
| ***Recycle, %*** | — | — | 98 | — | 90 |

1/6” Throat

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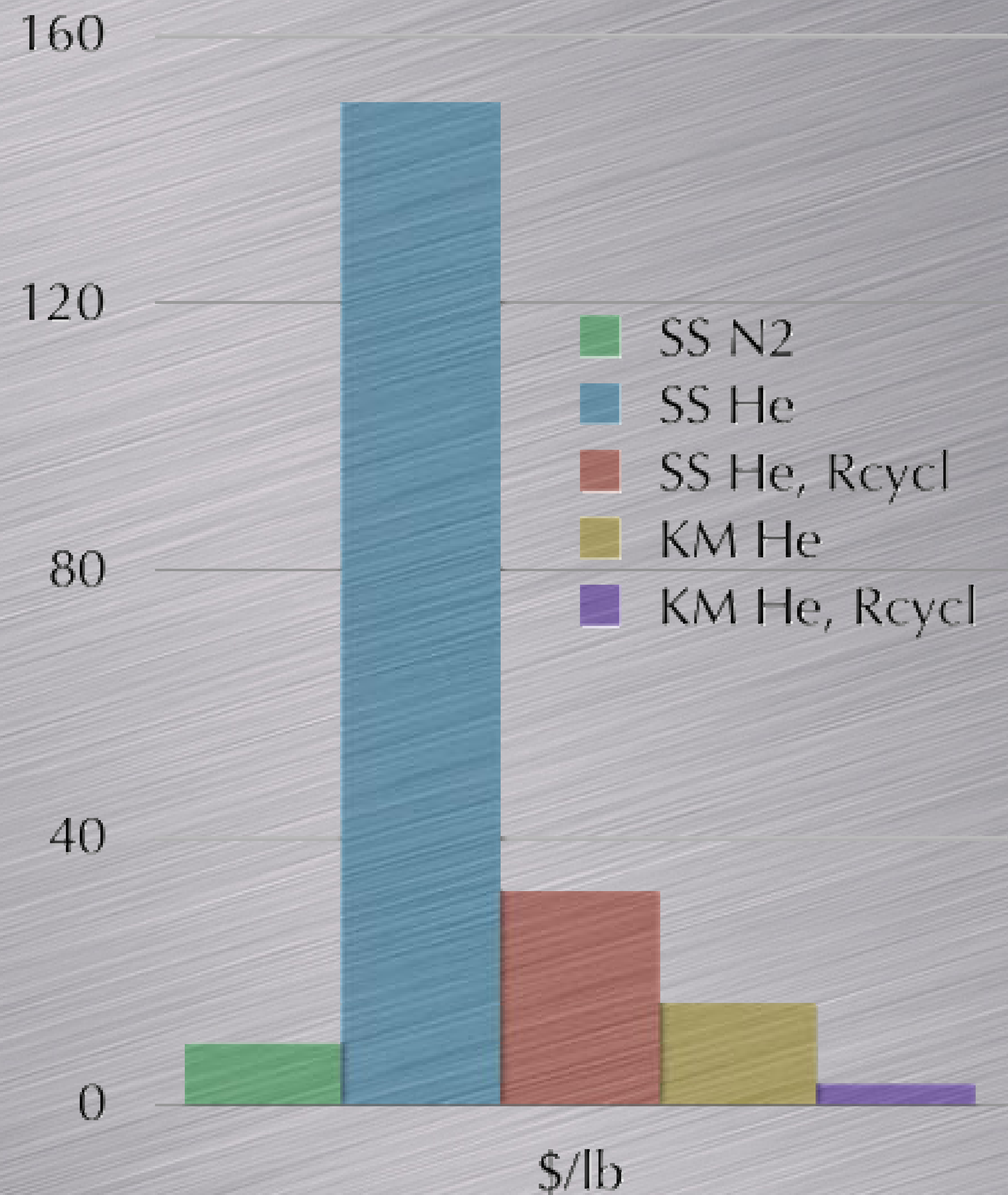
# Cost Summary

- Recycled KM is the lowest cost
- Once through KM is lower cost than recycled SS He



# KM Examples

- Cu-Cr on Cu alloy (Narloy Z)
- Nb on Cu alloy (GRCOP 84)
- Al-SiC MMC on metal foam
- NiCrAlY on Waspalloy
- Ti on Ti
- AlTrans on Steel
- WC-Co on 4340

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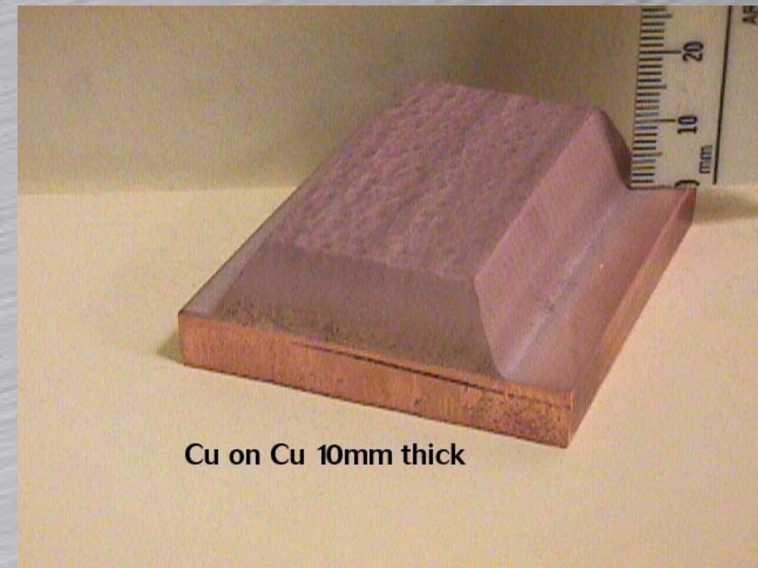
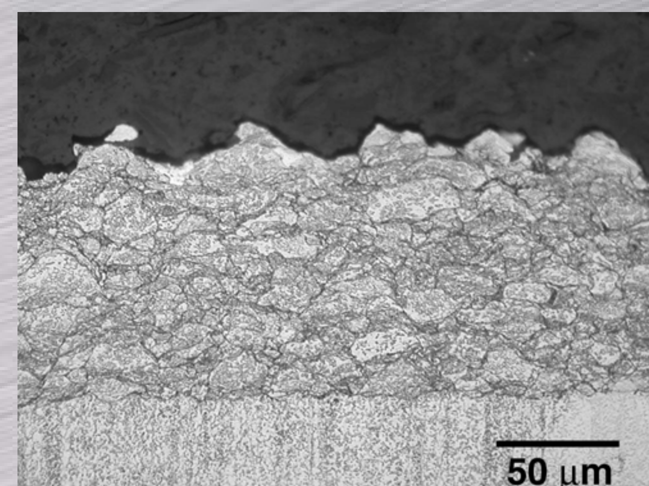
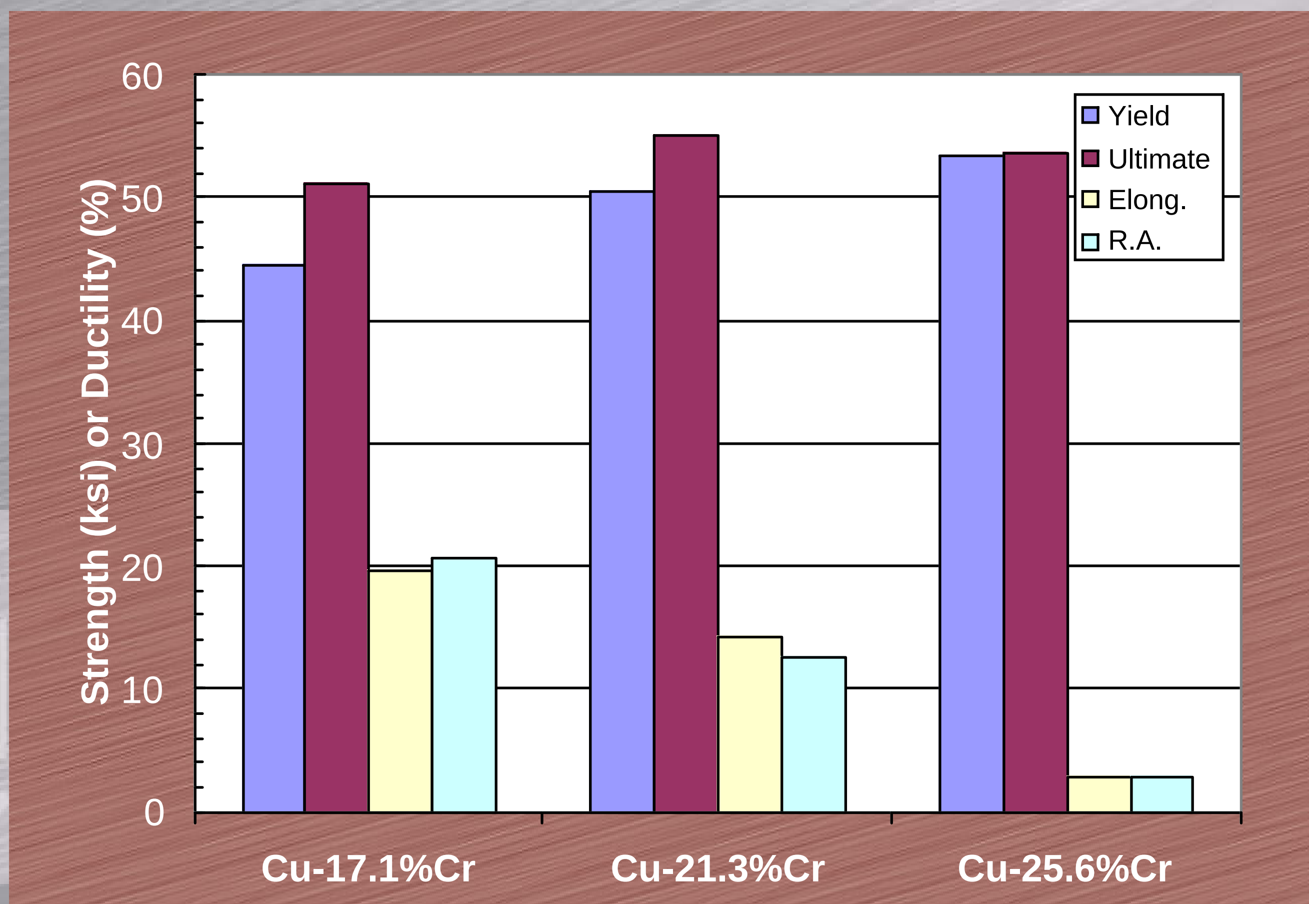
# Rocket Nozzle Coating

- Cu 21% Cr best compromise
  - Oxidation resistant
  - High thermal conductivity
  - High strength/ductility

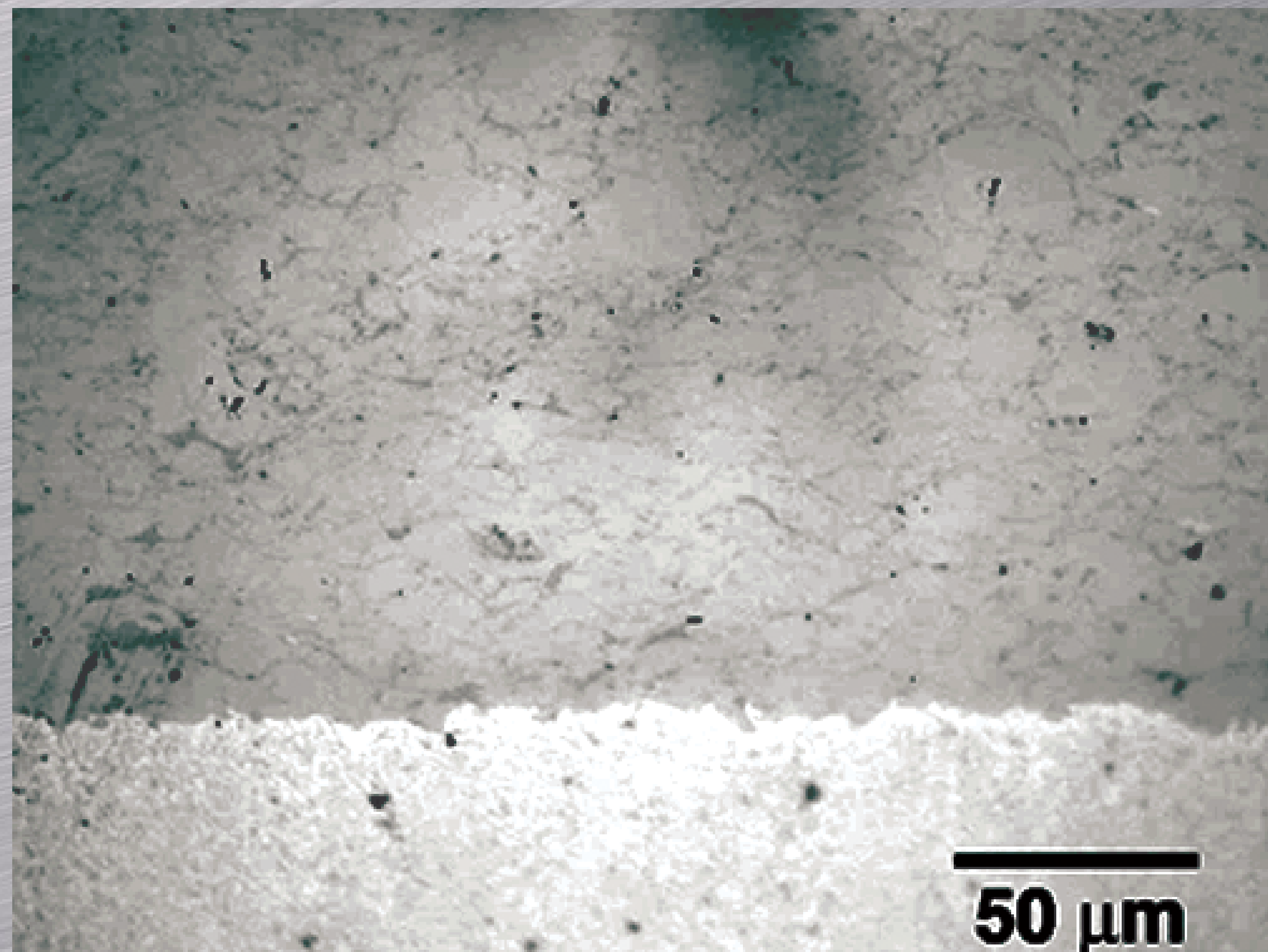


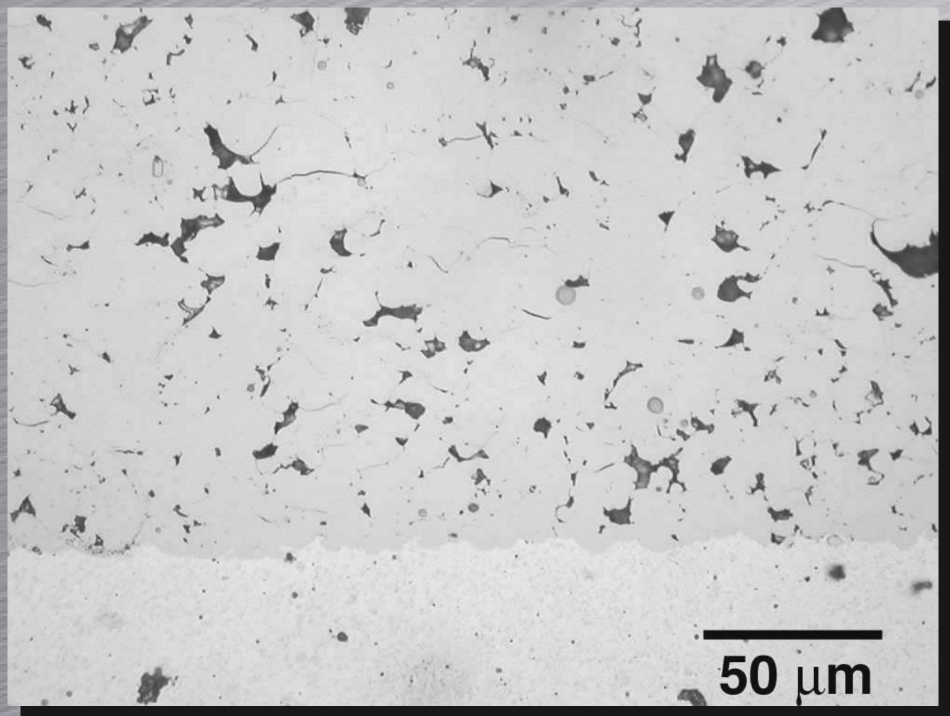
# Nb on Cu Alloy

- Allows bonding
  - Cu to Al
- Diffusion barrier
  - Cu / Al
- Prevents formation
  - of intermetallics
- Provides
  - Hermetic seal

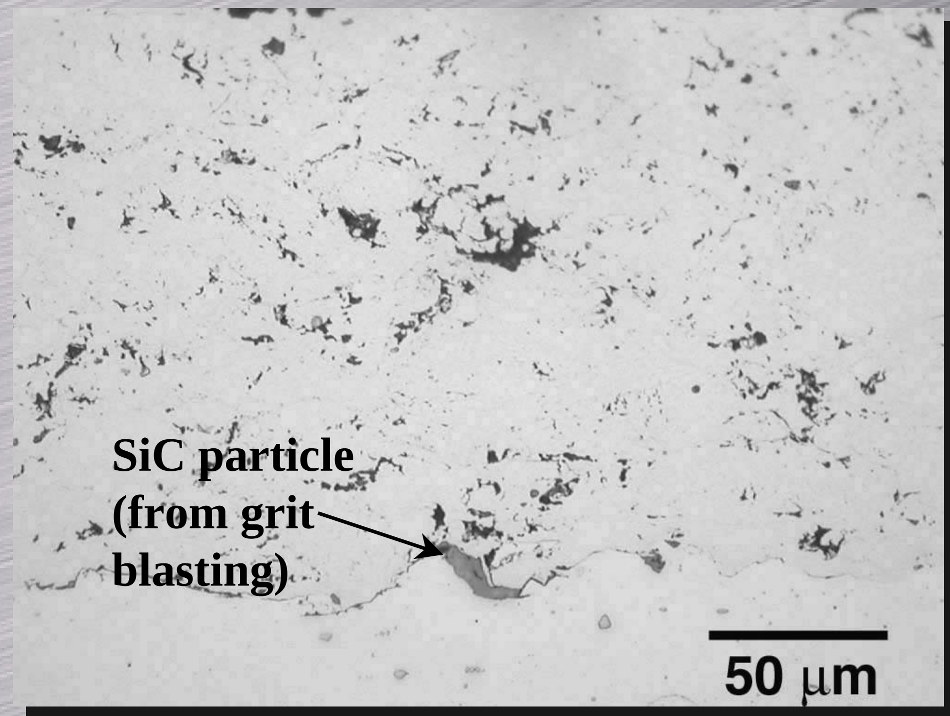


# The KM Alternative

KM NiCrAlY




HVOF CoNiCrAlY




| Process | Coating Composition | Substrate Material | Porosity | Adhesion Strength |
|---|---|---|---|---|
| **KM** | Ni-16Cr-6Al-0.5Y | Cu-8Cr-4Nb | 5.3% | >10.5 ksi (1) |
| **HVOF** | Co-Ni-Cr-Al-Y | Waspaloy | 5.4% | ~10ksi (2) |

(1) Failure in epoxy (Sebastian stud-pull test per ASTM C 633)
(2) Failure in coating (1.0” dia. epoxied loading fixture per ASTM C 633)

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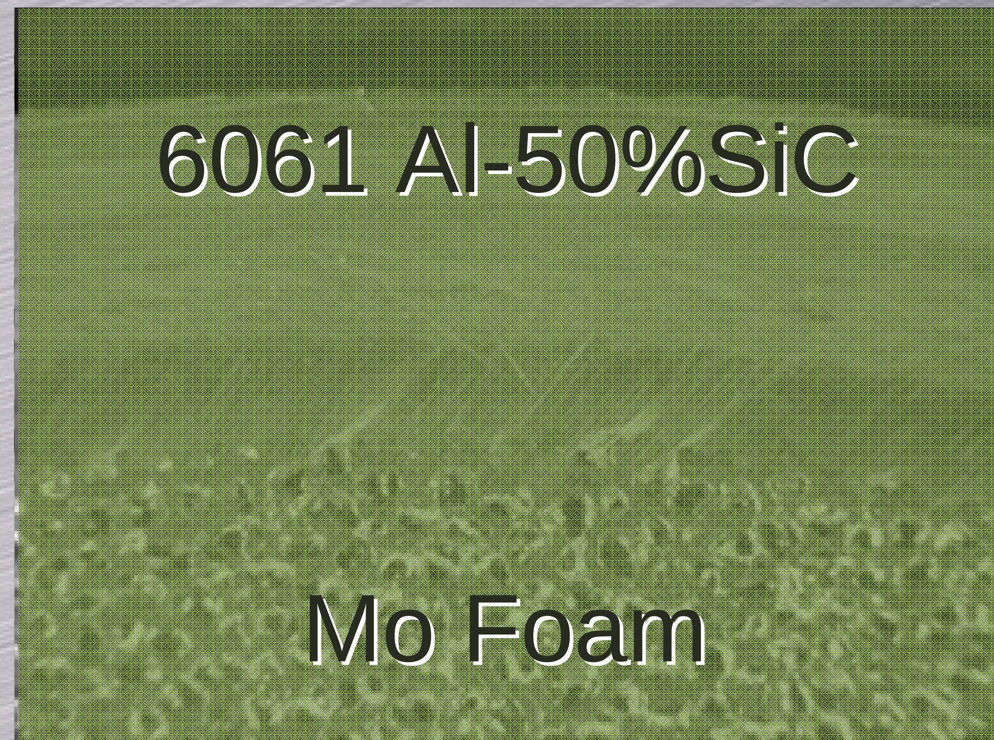
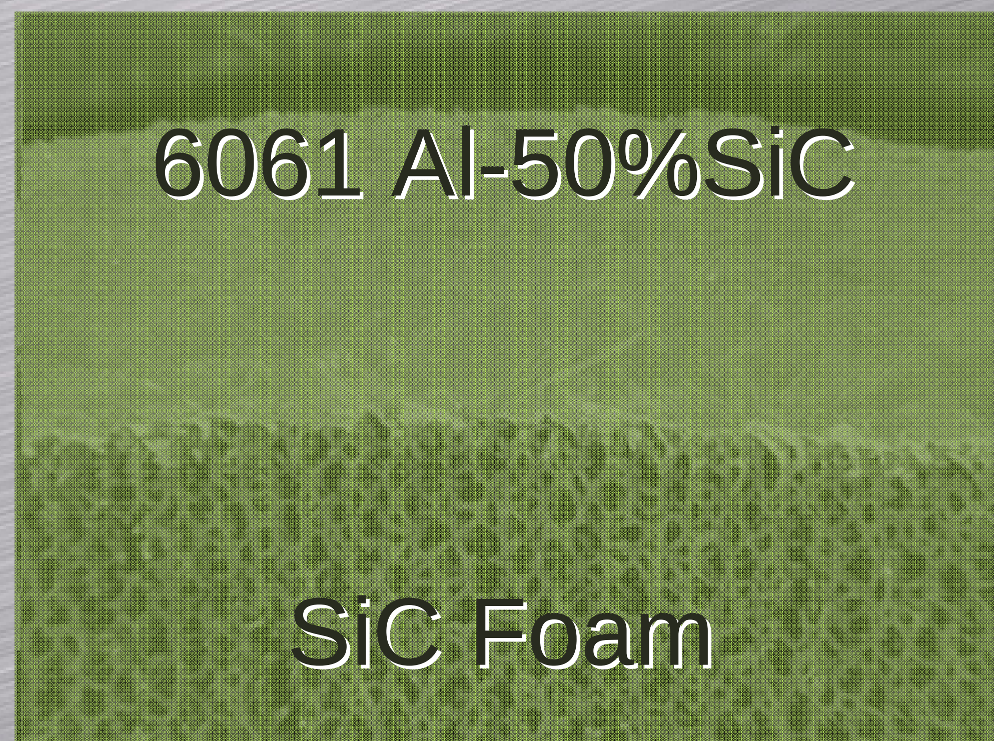
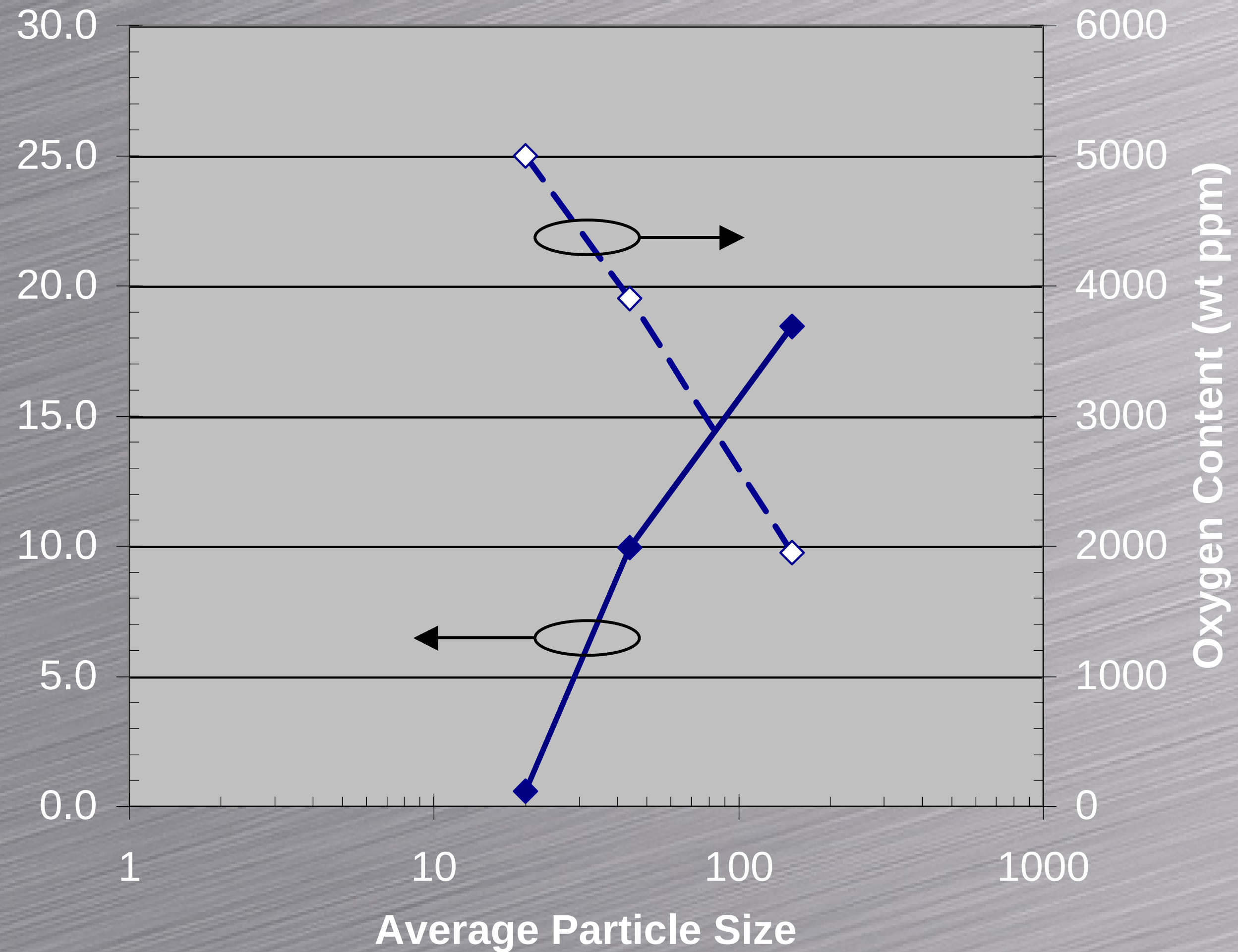
# Rocket Nozzle Jacket

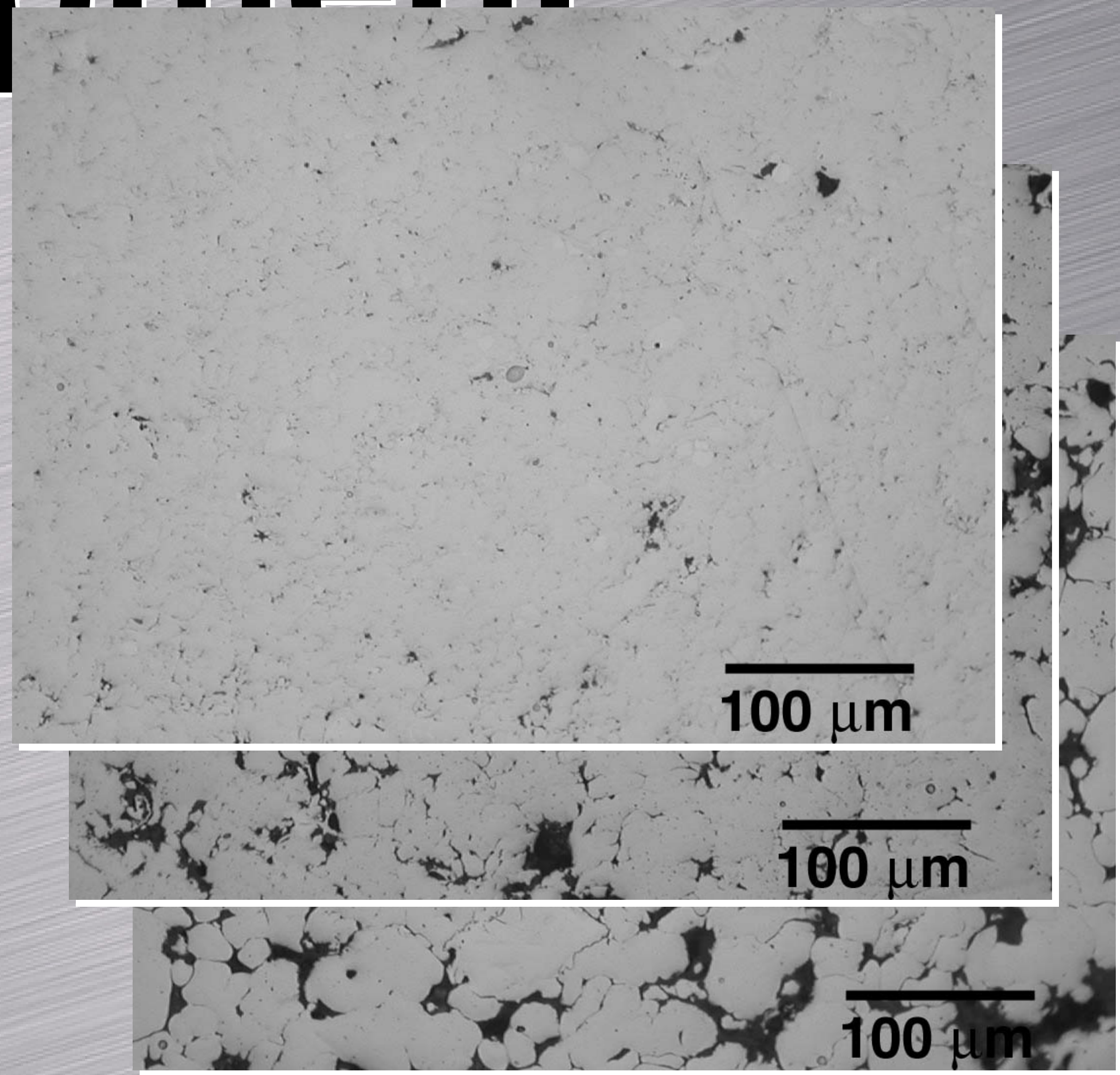
- KM Al-SiC MMC
  - Applied to porous metal foams
  - Mo top
  - SiC bottom
- Seals
- Provides Strength
- Matches CTE



# Ti Powder Development

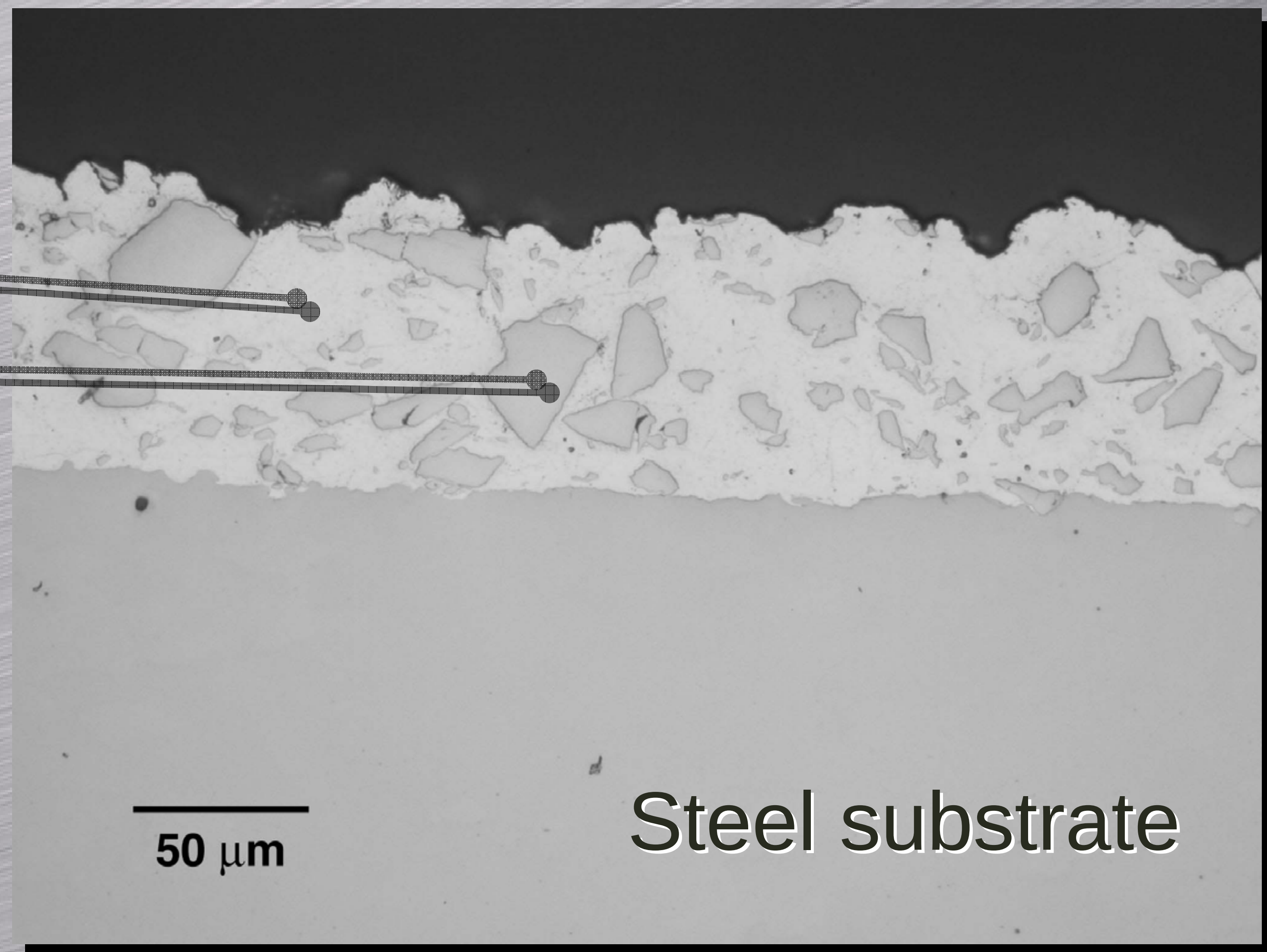



Application: Air Frame Repair

# Cd Replacement

- Al-Trans™ mixture
  - Aluminum
  - Transition metal
- Adhesion to
  - Substrate: ASTM B571
  - Paint: ASTM D2794, 120 ft-lb
- Corrosion
  - ASTM B117, 500 hrs



# KM Al-Trans™ vs ED Cd

| ***Shared Attributes*** | ***KM Al-Trans Superior*** | ***ED Cd Superior*** |
|---|---|---|
| Corrosion resistance | **No** H2 bake cycle | Threaded fasteners |
| Paint adhesion | **No** hazardous waste stream | Lubricity |
| Sacrificial | May be applied thicker | Oxide volume = metal volume |

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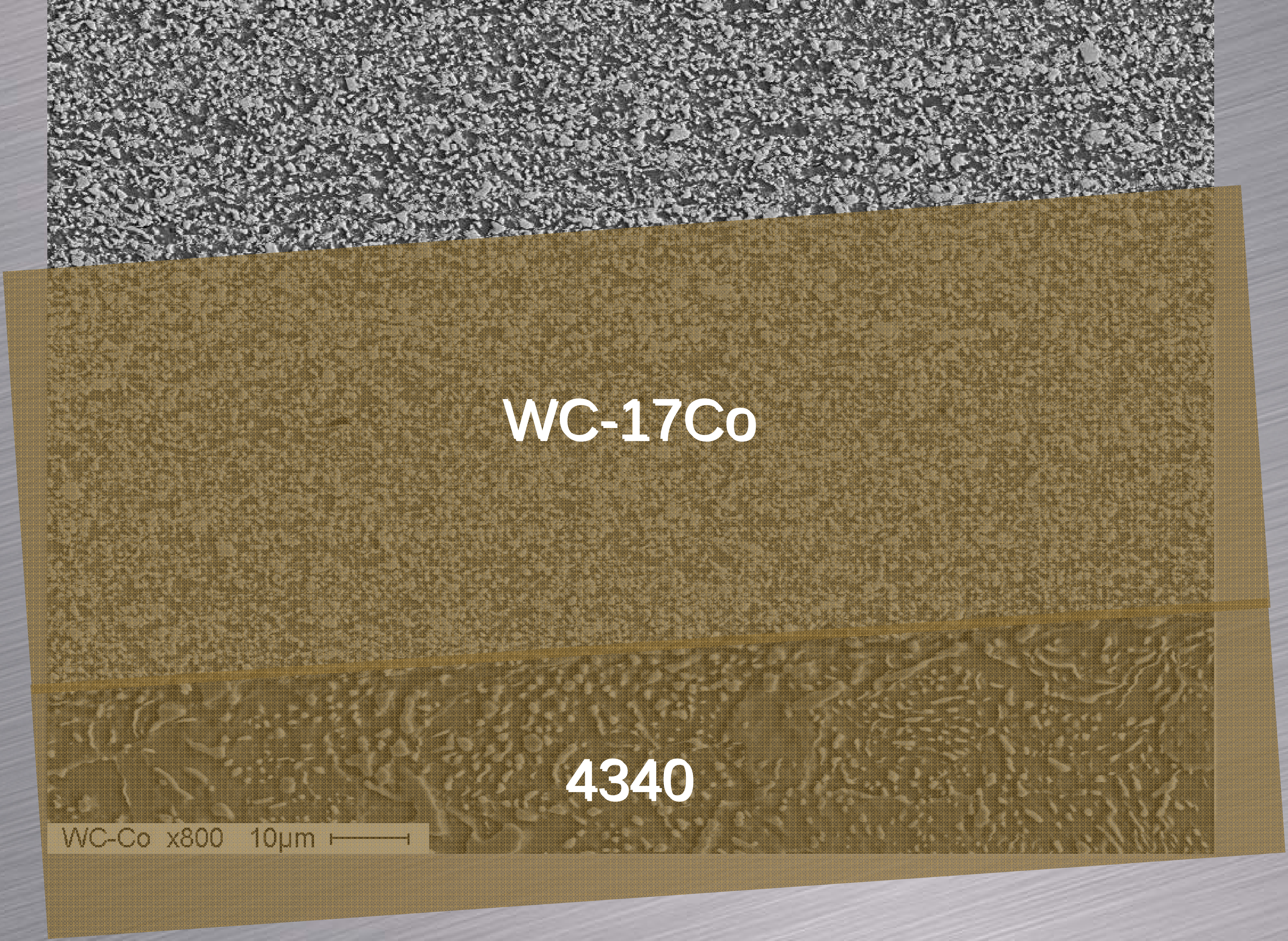
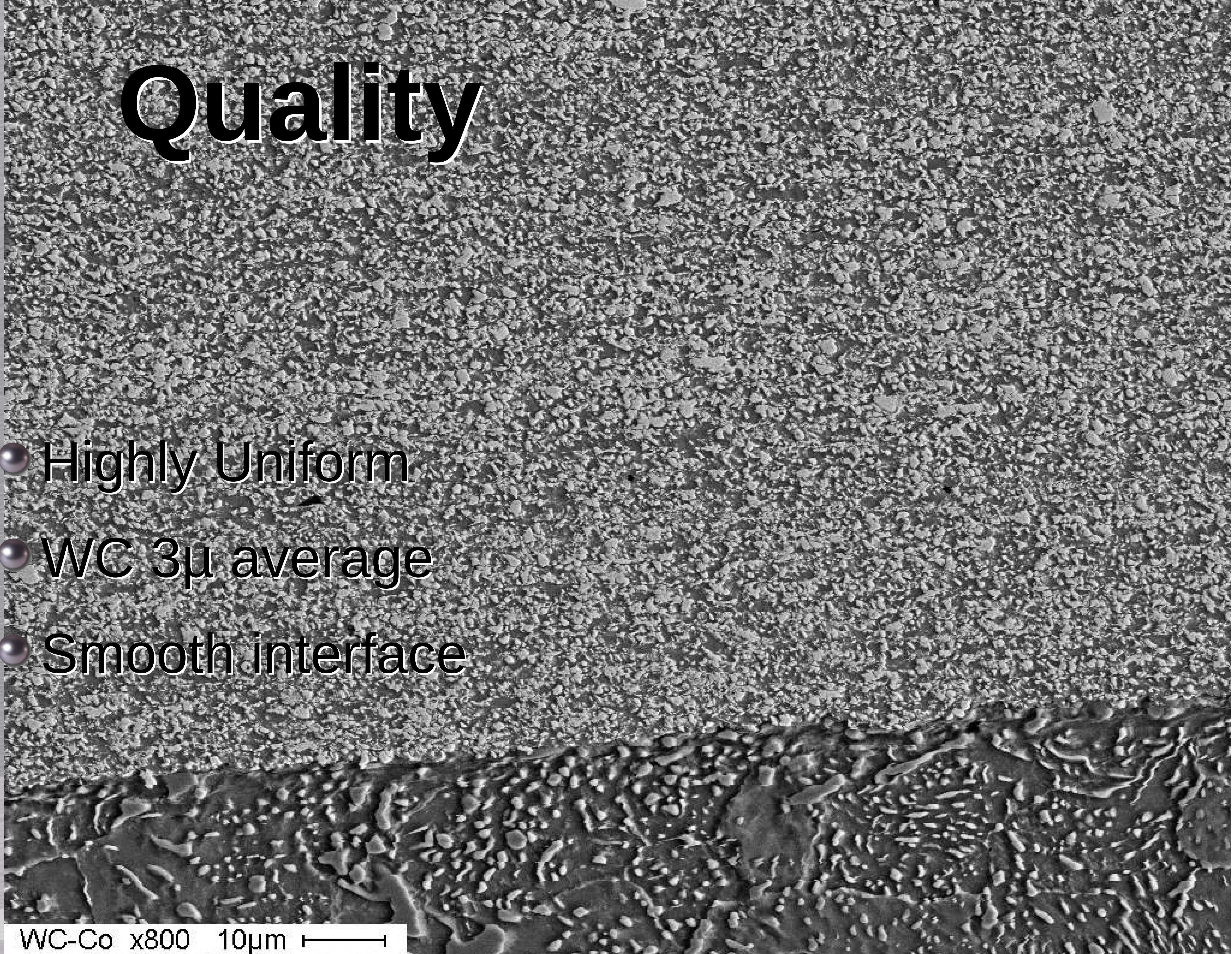


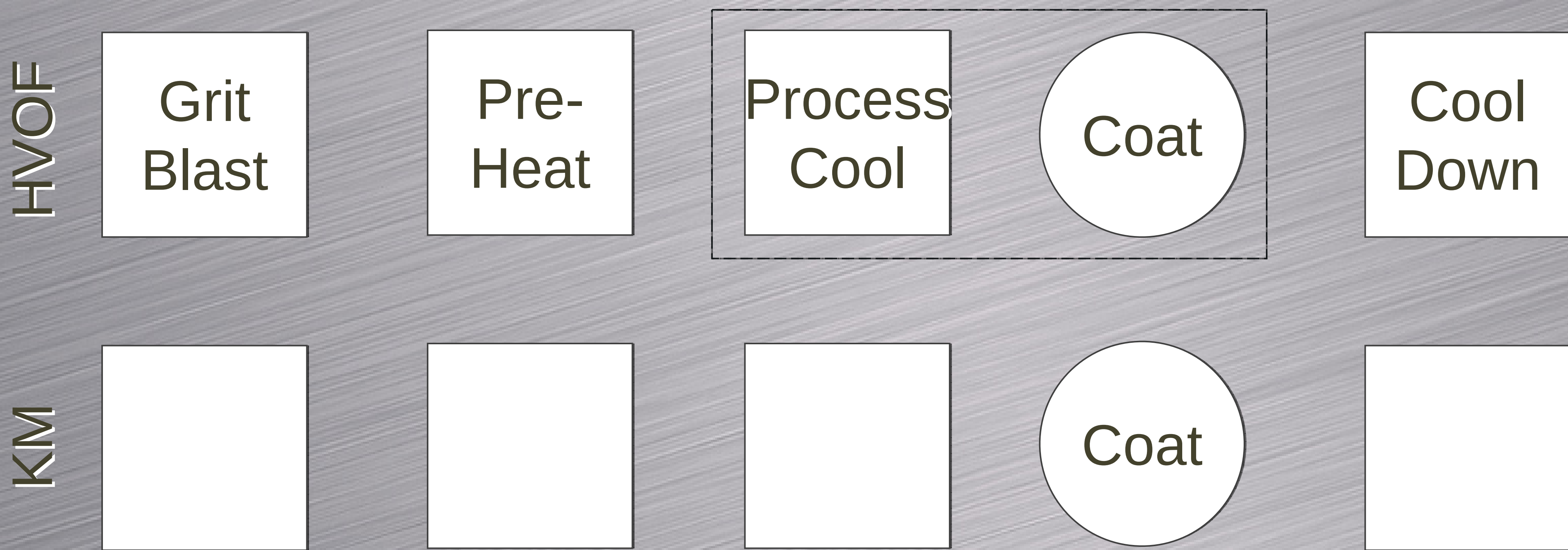

# KM Alternative

# Quality

- Highly Uniform
- WC 3μ average
- Smooth interface



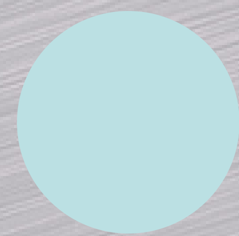
# Process Simplification



# KM WC-Co

| *Eliminates* | *Enhanced* |
|---|---|
| Grit Blast | Fatigue resistance |
| Preheat | Throughput |
| Process cooling | Simplicity |
| Cool-down | Throughput |
| Heat distortion | Usability |
| Masking | Throughput |
| Sharp transitions | Fatigue resistance |
| Porosity | Ductility |
| Oxide inclusions | Ductility, corrosion resistance |
| Explosive Gases | Safety |

# KM Particle

| |  |  |
|---|---|---|
| Hight | H | 0.2 H |
| Volume | V | V |
| Area | A | 3.34 A |
| Strain perpendicular | — | -80% |
| Strain parallel | — | 334% |
| Impact Velocity | | 1 km/s |
| Shear Velocity | | 4.2 km/s |

# PEWG Review

- Endorsed by OC-ALC and DoD JPCC
- Assess and verify KM for
- Repair and manufacturing GTE components
- Request AF Materiel Command, FY05 environmental funding